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Tools for Optimizing Timber Product Mix:

User's Guide for Visualizer-Buck

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Forest Research Information Paper No. 174

Tools for Optimizing Timber Product Mix:

User's Guide for Visualizer-Buck

Wojciech T. Zakrzewski[1], Frank Schnekenburger[2] and Peter Kozlowski[3]

[1] Ontario Forest Research Institute, Ontario Ministry of Natural Resources, 1235 Queen St. E., Sault Ste. Marie, Ontario, Canada P6A 2E5

[2] Spatialworks, Sault Ste. Marie, Ontario

[3] Forcomp Forestry Consulting, Ltd., London, Ontario

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Abstract

Resource managers require information about the amount and types of timber that can be produced from forest stands. Here we present information about two software programs, Visualizer V. 2.0 and BUCK V. 2.0, which facilitate managing stem profile data, fitting taper models, and producing optimized, locally valid and therefore legally defensible, individual-tree-based timber product mix yield tables. The suggested solutions are applicable for any tree species of single stem form. Briefly, round-wood timber products are defined by the user who determines desired size limits (length, minimum diameter) and rankings of log categories (sawlogs, veneer logs, etc.). Those rankings are assumed to reflect market value of timber products. To produce stand-level estimates, output from the software can be linked with most operational timber cruising applications that generate tree-species-specific data such as (a) breast height diameter, (b) tree total height (measured or estimated), and (c) number of trees of given size per unit area. As well, we provide guidance for using the software.

Resume

Outil pour optimiser le mélange de produits du bois : guide de l'utilisateur pour Visualizer et Buck

Les gestionnaires de ressources ont besoin d'informations au sujet de la quantité et des types de bois qui peuvent être produits par les peuplements. Nous vous présentons ici de l'information sur deux logiciels, Visualizer V. 2.0 et BUCK V. 2.0, qui facilitent la gestion des données sur le profil de tige, l'adaptation des modèles de décroissance et la production de tables du rendement du mélange de produits du bois fondées sur les arbres isolées qui sont optimisées, valides à l'échelle locale et par conséquent légalement défendables. Les solutions suggérées sont valables pour n'importe quelle essence à tige unique. En bref, les produits de bois rond sont définis par l'utilisateur qui détermine les limites de taille désirées (longueur, diamètre minimum) et les classements des catégories de bûche (grumes de sciage, grumes de placage, etc.) On présume que ces classements reflètent la valeur marchande des produits du bois. Pour produire des estimations au niveau du peuplement, on peut relier les données de sortie du logiciel à la plupart des applications d'inventaire forestier opérationnel qui produisent des données propres à une essence comme (a) le diamètre à hauteur d'homme, (b) la hauteur totale de l'arbre (mesurée ou estimée) et (c) le nombre d'arbres d'une taille donnée par unité de surface. De même, nous fournissons des conseils pour l'utilisation du logiciel.

Acknowledgements

We thank Bill Kissick, formerly with Ministry of Natural Resources' (MNR) Forest Business and Economics Section, for initiating the SMDS project, and our Canadian and U.S. partners for their contributions. SDMS was developed in support of the Great Lakes Stem Profile Modelling Project (GLSPMP), established by MNR's Ontario Forest Research Institute in partnership with the Michigan, Minnesota, and Wisconsin Departments of Natural Resources (DNR), and the USDA Forest Service, with support from Michigan State University, to improve local timber product estimates and enable cross-border comparisons of the productivity potential of forest sites within the Great Lakes region. Also we appreciate support for software development and/or comments on previous versions of the manuscript from William Cole and our regional partners, John Parton, Bill Towill, Dan Corbett, Colin Bowling, and Scott McPherson, all with MNR. Comments from two reviewers helped to improve the readability of the manual.

Contents

Abstract iii

Resume iv

Introduction 1

Tree Stem Data Management System (SDMS) 2

Visualizer V. 2.0 3

Instructions for Using Visualizer 4

BUCK V. 2.0 6

Yield Tables 6

Models 7

Data Acquisition 8

Data File Format 9

Working Session 10

References 18

Appendices 19

Program access and installation instructions 19

Data sets included in SDMS 19

Introduction

Resource managers are interested in knowing how much of what types of timber products can be obtained from forest stands allocated for harvest. Generating an optimized yield table of the mix of products possible from a forest stand, however, is not a trivial task. This is especially true if the goal is to deliver a practical solution that is easy to apply at the operational level. And one that allows resource managers to use locally available stem measurement data to calibrate a statistically valid individual tree taper model and apply it to generate a legally defensible optimized timber product yield table for an inventoried population of trees or forest stand. Meeting these objectives requires that resource managers select a reliable taper model and have access to appropriate stem measurement sample data. And they can be more easily achieved if resource managers have access to a suite of sound, practical, and user-friendly computer applications to calibrate the model and to generate yield tables with the desired and/or optimal mix of timber products.

Individual tree stem profile models can provide a robust and systematic way to link a raw commodity (stem wood) to timber end products. To generate reliable and legally defensible estimates of the amount of wood, such models should (1) have reasonably high predictive power and (2) meet the requirement for local validity, that is, they can be calibrated, for example, at the management unit level or within some ecologically meaningful spatial unit. The soundness and predictive power of a taper model depends on its design and its flexibility to reflect a variety of shapes of stem profile curves characteristic of different tree species growing across a range of forest sites and ecological regions in stands of varying densities.

Stem profile models have traditionally been calibrated by researchers *a priori* and simply provided to users with predetermined coefficients. The weakness of this approach is that such models are often calibrated using data from large regions, such as all of Ontario or even larger areas, resulting in large bias when applied to smaller regions. Using a mixed model approach to localize a model and lower the bias is a valid option. This technique is used in Ontario (as suggested by Jayaraman and Zakrzewski 2001) for generating localized height-*DBH* curves using the operational software *Ontario Height Curve Maker - OnHCM V. 1.0* (Zakrzewski, unpublished). To date, however, little progress has been made in implementing mixed models to model stem taper. An alternative approach to ensure local validity of taper model predictions is to calibrate the model for regional and stand-specific growth conditions using local data.

In Ontario, and possibly elsewhere, resource managers do not have ready access to a suite of tools to integrate their tree measurement database with the process of defining a taper model and generating tree-level optimized yield tables. This is because most taper models are not mathematically tractable and thus cannot be efficiently used for this purpose. Mathematical tractability of a taper model is commonly understood as the amenability of a specific taper equation to be presented (used) as a set of compatible closed-form expressions to produce exact estimates (obtained in one calculation step, with no iterations) for a sectional wood volume, height location of merchantability size, or cumulative wood volume. Intrinsic linearity is a desired feature of a mathematically tractable taper model because it makes it easy to develop associated computerized, automated linear regression fitting algorithms.

The mathematically tractable taper modelling solution suggested by Zakrzewski (1999) has the desired features discussed above and seems to be a valid option for computerized applications to be used by forestry practitioners in Ontario and elsewhere. This practical modelling framework (see Zakrzewski 2004) was implemented, for example, in forest inventories by the Michigan Department of Natural Resources. The taper model is incorporated in the software BUCK, developed by Sylvania International, Ltd. Since 1998, BUCK, which assists users to produce as many variants of an optimized timber product mix table as desired, has been used by forest industry as well as by the Ontario Ministry of Natural Resources to estimate provincial softwood lumber product mixes and economic values. Until now, however, BUCK was not integrated with any database or data formatting software and data input was overly labour and time intensive.

Stem measurement data are needed to calibrate taper model. To provide a formal structure for gathering and managing many stem measurements from across the Great Lakes Region as well as those from other jurisdictions, a Stem Data Management System (SDMS) was created (Zakrzewski and Schnekenburger 2006).

Visualizer V. 2.0, which is integrated in SDMS, is the software that facilitates management of stem measurement data stored within SDMS and automatically formats data to meet the requirements of the BUCK software.

Changes in timber product prices may warrant comparisons of options for merchandizing (bucking) available growing stock. This can be easily accomplished using BUCK, also integrated into SDMS, which assists users in optimizing timber product mix tables. The optimization is performed for individual trees on the basis of ranking timber products by limiting log lengths and diameters, which assures maximum value of the timber product mix.

This report provides information about the two software programs, Visualizer V. 2.0 and BUCK V. 2.0, which provide users with a suite of integrated applications to manage stem profile data in a relational database, perform visual and quantitative analyses of their own or other available stem taper data, calibrate taper equations, and produce optimized local timber product mix yield tables. More detailed descriptions of the software and embedded applications are provided in the next section, followed by detailed instructions for using the software.

Tree Stem Data Management System (SDMS)

The stem data management system (SDMS) was developed to facilitate the collation, management, and processing of stem analysis data for the Great Lakes Stem Profile Modelling Project (GLSPMP) (Figure 1) from the Great Lakes ecological region. However, the tool can also be used in other jurisdictions.

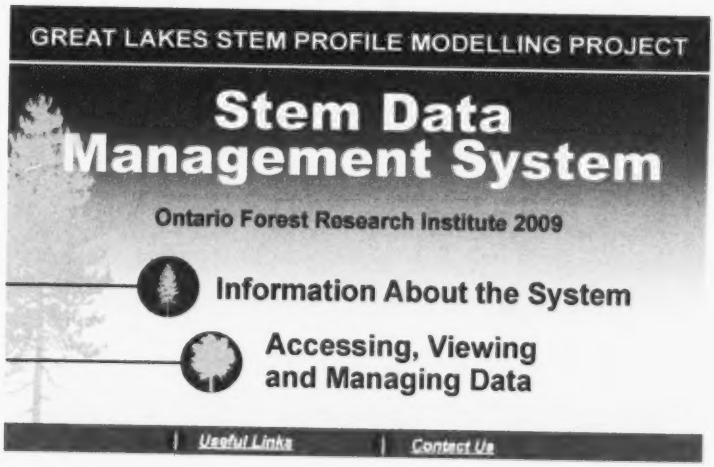

GREAT LAKES STEM PROFILE MODELLING PROJECT
Stem Data Management System
Ontario Forest Research Institute 2009
Information About the System
Accessing, Viewing and Managing Data
Useful Links
Contact Us

***Figure 1**. Main page of the Great Lakes Stem Profile Modelling Project website.*

SDMS is designed to allow users to integrate data from a variety of sources and formats into a single unified database, primarily for use in stem profile modelling. SDMS houses data in a consistent format (regardless of source) as well as the software modules used to process that data. Processing tasks included in SDMS are:

- Translating data from external structures, standards, and formats to that used in the database
- Validating data to check for errors and identify problem records
- Importing validated data into the database
- Exporting subsets of data from the database for analysis (i.e., fitting taper models)

In the existing system, processing is accomplished using SAS V. 9.1. New data sets can be added to SDMS as needed. These would need to be formatted as per the sample data available from the GLSPMP web site: http://ofri.vancouversolidcomputing.com.

Two components of SDMS are the software packages Visualizer and BUCK (pubiic domain, maintained by the Ontario Forest Research Institute, Sault Ste. Marie, Ontario). Visualizer is used to scrutinize, edit, and clean stem measurement data. The package facilitates data management, i.e., maintains the integrity of the original data (the software does not overwrite the original input file) and allows the user to create subsets by selecting relevant measurement records by owner, geographic location, tree species, or stem sizes (i.e., breast height diameter or height). These data sets can be exported and saved in MS-Access format or in a format compatible with the BUCK software (*BUCK format*).

BUCK facilitates the generation of locally reliable timber roundwood product yield tables (conditional on the quality of available local data). User-generated tree-level optimized timber product mix tables are based on user-specified timber product sizes (lengths and diameters of logs or poles) and ranking of product desirability (e.g., as determined by current market prices). The term "local" refers to a user-defined stratum represented by the data accepted to define (or fit) the taper model used by BUCK (for details about the model, see Zakrzewski 1999, Zakrzewski and MacFarlane 2006).

The link between Visualizer and BUCK is that Visualizer can be used to format stem measurement sample data to run BUCK. Using Visualizer to pre-process stem analysis data for use by BUCK greatly simplifies the data input process and provides an elegant solution for managing large quantities of stem analysis data. However, BUCK can also be used as stand alone software, provided the input data are correctly formatted (see Data Entry section below).

Visualizer V. 2.0

Visualizer V. 2.0 (Figure 2) facilitates the management of stem measurement data stored within SDMS by allowing users to:

- Filter subsets of data from the original data (by owner, region, tree species, size range)
- Produce basic descriptive statistics: tree count, measurement count, minimum and maximum of breast height diameter (*DBH*) and tree height for selected data
- Produce *DBH* frequency distribution bar graph (within user defined classes)
- Produce stem profile graphs (inside/outside bark)
- Edit data (implements corrections and immediately displays adjusted graphs)
- Format data and save in a format compatible with BUCK.

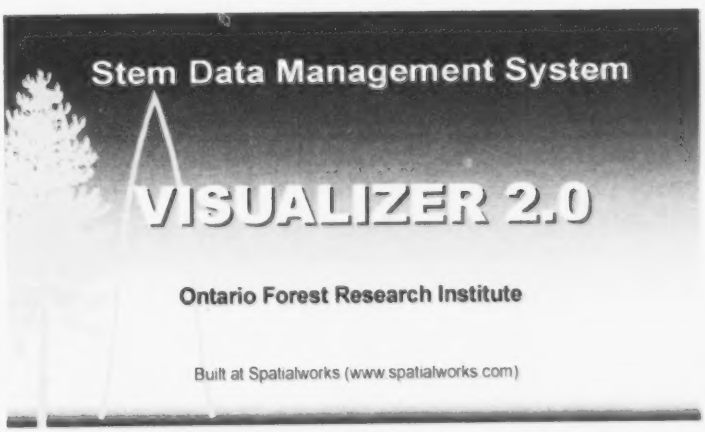


***Figure 2**. Splash page of Visualizer software.*

Instructions for Using Visualizer

After starting the program, a blank template window is displayed. To access data, the following steps are required:

·Select preferences

Select measurement units (imperial or metric) and *DBH* class width (this will be used to display diameter frequency distribution) (Figure 3)

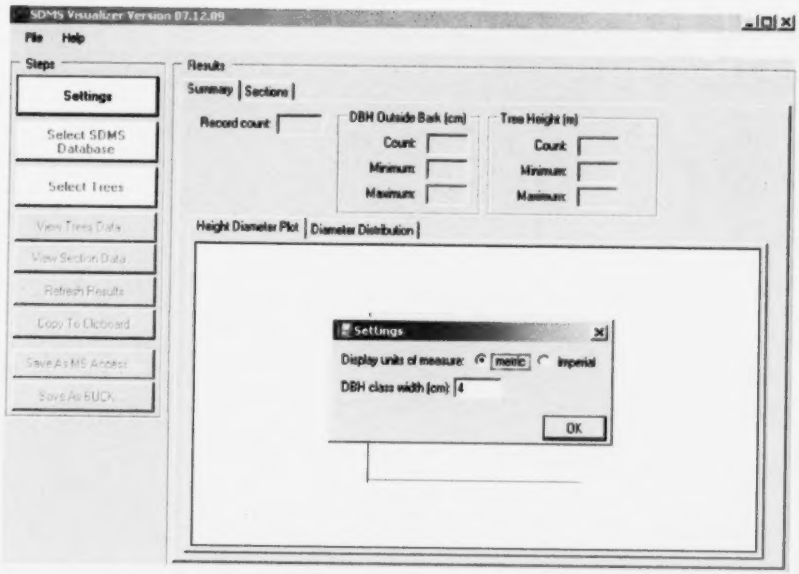


Figure 3. *Visualizer software window showing the settings options.*

·Select database

Select *SDMS database* to define the file in which the data is stored.

When the source file is defined, use *Select Trees* to define specific database by owner, jurisdiction, and tree species. A desired range of sizes, *DBH*s, and heights may also be defined here.

The program reads the requested data and plots (for the selection) heights vs. *DBH* and a *DBH* distribution bar graph, as well as producing a summary of tree sizes.

•Screen stem measurements

Scrutinize stem sectional measurements (outside and inside bark), tree by tree (Figure 4). If erroneous or undesired measurements are displayed, use *View Tree Data* or *View Section Data* to display data source tables and make necessary changes or deletions. When a record in the table is changed, the graph will reflect that change. Individual graphs can be copied to clipboard and saved for future reference.

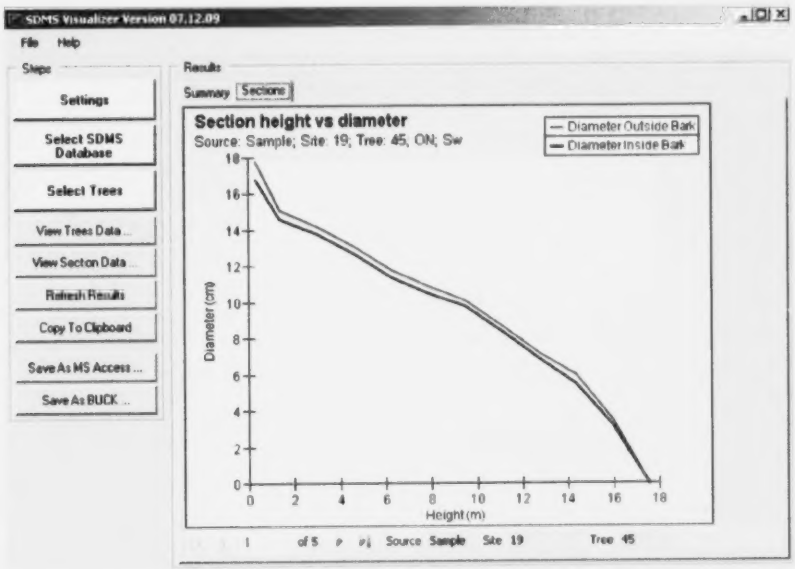


Figure 4. *Example of stem-specific diameter measurements displayed in Visualizer.*

•Save data

Save the data in one of two formats: (1) as an MS-Access file (accessible to Visualizer) or (2) in BUCK format.

Regardless of the number of tree species, one MS-Access file is created if that option is selected. The software will prompt for a file name (*.mdb).

Executing the *Save as BUCK...* command generates multiple files (one per tree species) with a species code used as name and the extension .dat (e.g., jack pine data will be saved as Pj.dat). Note that BUCK output will overwrite files (within the same folder) without warning. (Either renaming files and/or organizing them in appropriately named folders will help users to track the data used to generate the taper models used in BUCK.)

BUCK V. 2.0

BUCK is software (Figure 5) that can be used to produce locally valid, optimized yield tables (wood volume in m^3 or cubic feet) of timber roundwood products.

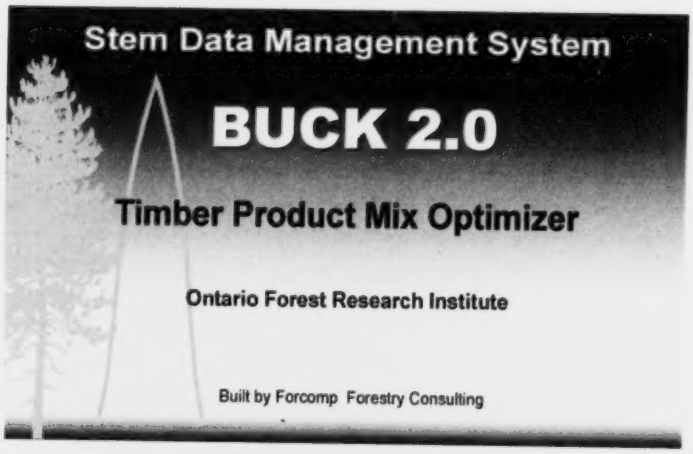


Figure 5. *Splash page of BUCK software.*

Yield Tables

BUCK's local yield tables are based on estimating volume of an individual stem (or a stem section) inside- or outside bark. This is achieved through the application of a locally valid tree taper/volume model (Zakrzewski 1999) that requires a tree's *DBH* and total height (*H*) as input, where *DBH* is the outside-bark breast height diameter (i.e., diameter measured 4.5 ft from the ground in the imperial system or 1.3 m in the metric system). The table can be produced as hard copy, in BUCK format, or saved as a text file. The text file can be imported into a spreadsheet or other software and processed as desired (e.g., linked to software supporting operational timber cruising).

Generating locally reliable yield tables with BUCK involves the following steps:

1. Acquire local species-specific stem analysis data
2. Enter the data manually or import a text file (e.g., created by Visualizer V. 2.0)
3. Calibrate models (done automatically by the software)
4. Define timber product standards
5. Obtain the table in desired form (hard copy or electronic file in BUCK or text file format)

Models

To produce yield tables, three models are used in BUCK:

- Stem profile (taper) model
- Height-diameter curve
- Double bark thickness line

A mathematically tractable variable-form taper model (Zakrzewski 1999) is used to compute the volume of any bole segment or to any merchantability limit. (*Variable-form* means that trees of the same *DBH* but different height have a different form factor.) As the model is intrinsically linear, ordinary least squares (OLS) weighted regression is used to define the model coefficients (cross-sectional areas are used as a weight). Bark thickness at *DBH* is estimated from a separate linear regression model. The taper model can describe either outside- or inside-bark cross-sectional areas (ca_z) along relative stem height locations z:

$$ca_z = \frac{K\,(z^2 + \beta\, z^3 + \gamma z^4)}{z - s}$$

where z is defined by height location h of a cross-sectional area relative to total tree height H ($z = 1 - h / H$), K is an individual tree-specific scaling constant, and $s = 1 + \delta\, H/DBH$ assures that the model is appropriate for both natural stands and plantations (it is sensitive to stand density). Zakrzewski's taper model has been shown to account for the influence of thinning treatments on stem shape of red spruce and balsam fir in New Brunswick (as documented by Pitt and Lanteigne 2008). The model was also reported to be applicable across site conditions for young aspen (Ter-Mikaelian et al. 2004). Other tests of the model also produced positive results (see, e.g., LeMay et al. 2008, Jiang and Brooks 2008, Li and Weiskittel 2010).

A linearized form of Zakrzewski's model is calibrated by BUCK using a weighted ordinary least squares (OLS) linear regression technique. Two coefficients (β and γ) are obtained from the BUCK model fitting procedure. Coefficient δ is treated, by default, as a constant, and set equal to 1. A set of 3 coefficients (β, γ, and δ) can be obtained from calibrating Zakrzewski's (1999) model independently, outside BUCK, and then applied (entered into BUCK) to calculate respective predictions using data sets imported into BUCK.

The height-*DBH* model is an intrinsically linear two-coefficient modified asymptotic Schumacher model:

$$H = 1.3 + \alpha_1 \exp(\alpha_2 / DBH)$$

It is calibrated using OLS linear regression after logarithmic transformation. An **<Enter Model>** option is provided to apply user-specified coefficients of locally valid standard height curve in place of those generated by BUCK.

The double bark thickness factor (*DBTF*) line is derived as a one-coefficient regression relationship (no intercept) between the bark thickness and *DBH*. This model is needed only when inside-bark volume is of interest. When bark thickness cannot be defined using stem-analysis data entered into BUCK (less than 3 bark thickness measurements), the user must provide an appropriate *DBTF* as a percentage of *DBH*.

Data Acquisition

To generate timber product yield tables for inside- or outside-bark tree volume, tree species-specific stem analysis data are needed. Options are to use readily available (formatted) data from Visualizer V. 2.0 or to collect new data and format it to be compatible with BUCK. Use of existing data, collected in the local area of interest, would be the first option to consider. Collecting new measurements is not a simple task and requires both knowledge and experience; however, it may be a necessary investment to ensure legal defensibility of local estimates of timber product volumes. In Ontario, the Ministry of Natural Resources (MNR) has generated an extensive stem measurement database (see Appendix 1), and regional and provincial growth and yield specialists can provide recommendations about which data sets are preferred for a given area.

Sample measurements should cover a range of stem sizes and *HDR*s (height/*DBH* ratios related to tree status within a stand) across stands, and across stand densities for a specific region. To guide data collection, stand density could be measured, possibly using a relative density index (stand density management diagrams are useful for this purpose). The absolute minimum data set size is 3 sample trees but 80 to 90 stems is more reasonable and will produce better results.

Mandatory tree data requirements are:

- Total tree height (from the ground to the top)
- Outside-bark diameter at breast height (*DBH*)
- Inside-bark diameter at breast height or double bark thickness at breast height (if inside bark volume estimate is desired)
- Inside-/outside-bark diameter measurements on a sample stem

Stem measurement protocols may vary, and possibly should address a need for recording locations of points of inflections along the stem (e.g., crown location). In practice, this requirement is hard to meet; however, it can be addressed by including a diameter measurement close to the base of the tree crown. In general, diameter measurements (outside- or inside bark, or both) should be available from the following locations: at stem heights of around 1 ft (0.3 m) from the ground, at *DBH* (1.3 m), at 6 ft (or 2 m) from the ground, and above at approximately 6 ft (2 m) intervals. Equal length of sections is not crucial; in fact, unequal length, especially when a sample consists of trees of similar total tree heights, would be beneficial for defining the taper curve.

If the stem cannot be measured at *DBH* (4.5 ft or 1.3 m from the ground) due to scars, branches, etc., it should be either discarded or *DBH* interpolated using measurements above and below where it would have been measured. Regardless, breast height location should be marked on the tree before it is felled. This mark is then used as a reference to mark all stem height locations (below and above *DBH*) for diameter measurements.

Tables providing inside-bark volumes require some measurement of inside-bark diameter at breast height to provide an estimate of bark thickness. If only a few trees (at least 3) have been measured for outside- and inside-bark diameter at breast height the software will use these measurements to obtain an estimate of the bark thickness to be applied to trees without bark thickness information. If the data set used for model calibration does not include inside-bark measurements, the user may enter a species-specific, locally valid double bark thickness factor (*DBTF*) as a percentage of *DBH* (outside bark). An estimate of *DBTF* might be acquired from the published data or additional local measurements on standing trees (possibly 15 to 20 trees): $DBTF = 100*(1 - 2\ BT/DBH)$, where *BT* is a single bark thickness measured with, e.g., a bark gauge. Entering a value for *DBTF* is possible only if fewer than 3 measurements are available for individual trees in the data set.

Note: *It is the user's responsibility to determine the quality and amount of data required for a given purpose; collecting the minimum may not provide yield tables of the desired precision and accuracy.*

Data File Format

Stem analysis data can be entered into BUCK manually, via a text file or using a spreadsheet program (the latter is recommended). Data to be imported must be in a text file format containing two header records followed by contiguous data records containing seven space, tab, or comma separated measurement parameters (see Table 1 for example). All files saved by BUCK in text format are comma delimited.

Table 1: *Example data file showing the tree stem data needed to use BUCK.*

SPRUCE, BLACK						
METRIC						
11518	20.6	19.6	18.32	0.15	24.6	0
11518	20.6	19.6	18.32	1.37	19.6	0
11518	20.6	19.6	18.32	3.05	18.2	0
11518	20.6	19.6	18.32	4.73	16.9	0
11518	20.6	19.6	18.32	6.41	16.3	0
11518	20.6	19.6	18.32	8.09	14.5	0
11518	20.6	19.6	18.32	9.77	13.2	0
11518	20.6	19.6	18.32	11.45	11.7	0
11518	20.6	19.6	18.32	13.13	8.9	0
11518	20.6	19.6	18.32	14.81	6.6	0
11518	20.6	19.6	18.32	16.49	3.3	0
11518	20.6	19.6	18.32	18.32	0	0
11519	22.9	0	18.47	0.15	25.4	0
11519	22.9	0	18.47	1.37	0	0
11519	22.9	0	18.47	3.08	19.7	0
11519	22.9	0	18.47	4.79	19.1	0
11519	22.9	0	18.47	6.5	18.5	0
11519	22.9	0	18.47	8.21	17.1	0
11519	22.9	0	18.47	9.92	15.2	0

In Table 1, the following information is required:

- Header record 1: Tree species name (30 characters or less, case insensitive).
- Header record 2: System of measurement (IMPERIAL or METRIC, case insensitive).
- Data records: Data records (rows) must not be separated by empty records. Heights and diameters may be entered with up to 2 decimal places. The required variable sequence (from left to right) in the records is:

1. Tree No. (a unique number for each tree; no need to sort/order)
2. *DBH* outside bark (breast height diameter at 4.5 ft or 1.3 m, in inches or cm)
3. *DBH* inside bark (in inches or cm) (if only outside-bark volume is of interest, enter zeros)
4. Total height (in ft or m ; up to 2 decimal places)
5. Height of measurement for diameter inside and/or outside bark
6. Diameter inside bark (in inches or cm) at the height specified in #5 above (if not of interest, enter 0)
7. Diameter outside bark (in inches or cm) at the height specified in #5 above (if not of interest, enter 0 or leave blank).

In Table 1, diameters outside bark (variable #7) equal zero. With this data set only inside-bark volume can be calculated for timber products. If both inside- and outside-bark diameters are provided, only one option can be selected and executed during the model calibration session. *DBH* inside bark (variable #3) for tree No. 11519 is not available; instead the software will use an estimate based on the double-bark-thickness/*DBH* regression relationship defined from known measurements (if there are more than 3).

We emphasize here that the user must assure completeness of the data. Visualizer and BUCK are automated tools that facilitate scrutinizing and/or cleaning of the data. Missing records (e.g., lack of DBH measurement) may result in automatic discarding of a sample tree when Visualizer exports the data to the BUCK file.

The number of measurement records entered in BUCK is limited only by available computing resources (system memory).

Working Session

Main Menu

Executing the program opens a window **BUCK - [BUCK1]**.

BUCK may be used as a multi-windowed program by selecting **<File>** and **<New>**, from the drop-down menu, to open additional working sessions (**BUCK - [BUCK2]**, etc.) for species-specific tree taper models or data sets.

Selecting **<Data/Model>** (Figure 6) results in the options **<Enter Data/Calibrate>** and **<Enter Model>**.

Select **<Enter Data/Calibrate>** to use a new data set to calibrate the models or to import and edit (modify) a previously used data set to re-calibrate the models. In either case, the end product is a set of models (accepted by user) to be used to produce locally valid yield tables.

Select **<Enter Model>** if, for the available data set, the models' coefficients are already known. These coefficients can be examined by applying them to the imported data set and, if satisfactory to the user, will be applied to generate a new yield table(s).

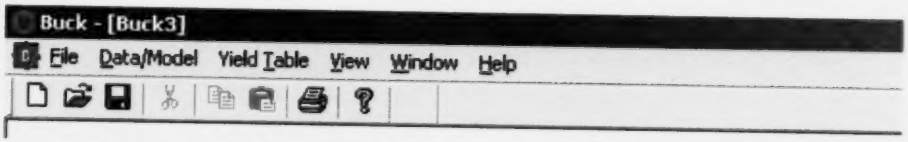


Figure 6. *Main menu of BUCK software.*

Selecting **<Yield Table>** results in the options **<New Table>** and **<Import Table>**.

Select **<New Table>** to generate yield tables using the calibrated models and the user specified standards.

Select **<Import Table>** to load a yield table previously saved in BUCK format (see description of the format below) for viewing, re-calibrating the model (generating a new table), or printing.

Data Entry

Entered data should be inspected carefully. BUCK provides many automated procedures to check the data; however, it is ultimately up to the user to decide if the data set is appropriate for calibrating the models. If the data format conforms to Visualizer's requirements, Visualizer can be of great help in this regard.

Manual Data Entry. The following data can be entered manually (see Figure 7):

1. **Species:** Enter the name of tree species (optional) separated by a space or any code with as many spaces as desired but not exceeding 30 keyboard strokes.
2. **Measurement system:** Select the system of measure (**metric** or **imperial**). Once selected, this cannot be changed during the data entry session. BUCK prevents the entry of tree data until after this choice is made.
3. **Stem profile:** Select the type of timber volume table(s) to be produced (**inside bark** or **outside bark**). This specifies the data to be used for model calibration. Data may be entered without choosing one of these options; however, the model will not be calibrated until one is selected.
    a. Begin entering data with ***DBH*** (outside bark and inside bark, if required) and **total height**. When the values for *DBH* and total height have been entered, BUCK automatically generates records for breast height (4.5 ft. or 1.3 m as appropriate) and the top height of the tree. If the ***DBH* inside bark** is not known for some trees, leave the cell blank (default is 0). If ***DBH* inside bark** is not available for any of the trees in the data set, enter a double bark thickness factor (**DBTF**) expressed in terms of a percentage of *DBH* (e.g., 4.5%; in this case, ***DBH*** outside bark will be multiplied by 0.955 for all trees to estimate ***DBH* inside bark**).
    b. Select **<Next Record>** to enter the next set of measurements for the same tree. During entry of a tree's data, constant values for the tree (tree number, *DBH* inside and outside bark, and total height) will automatically be entered into every record. When one of these values is changed in any record, it will be updated automatically in every record for that tree.
    c. Select **<Next Tree>** to enter data for a subsequent tree.

To prevent data loss, intermittently select **<Save Data>**. The data will be saved in a text file named by the user with a **.dat** extension that can be imported into BUCK.

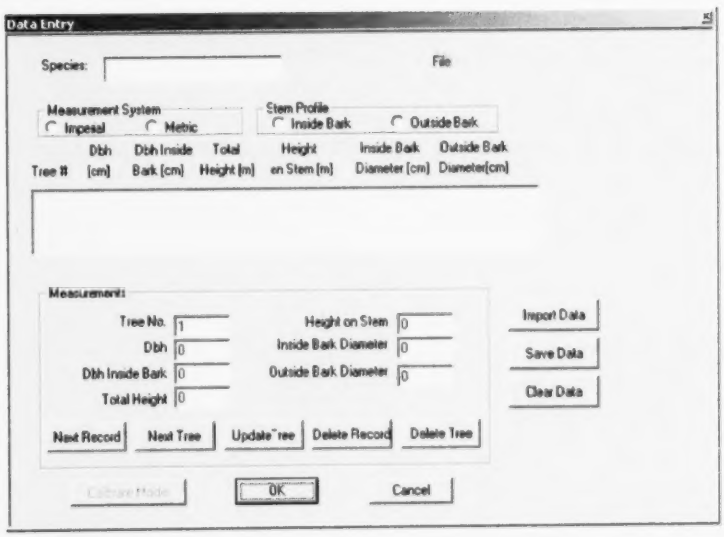


***Figure 7**. BUCK's data entry window.*

Importing data. Select the **<Import Data>** button to import stem analysis data for calibrating the models needed to generate a yield table. The data must be formatted as described in **Data File Format** (If Visualizer V. 2.0 was used and the data exported/saved in BUCK format, it can be imported directly).

Editing data. Values highlighted in the data display window are repeated in the Measurements section of the screen. These values may be edited by selecting the cell and entering the correct value. To execute changes, select **<Update Tree>.** This method of implementing changes to the data is not preferred; editing options in Visualizer V. 2.0 are the preferred option for screening data for input to BUCK.

Calibrating Models

To obtain the coefficients needed for the three models listed above (or two if **DBTF** is entered manually or if an outside-bark stem profile model is selected), select **<Calibrate Model>**. A screen indicating *Results of Yield Model Calibration Accepted by User* will appear.

Entering Models

This option applies when Zakrzewski's (1999) taper model is calibrated outside BUCK (e.g., with nonlinear regression methods). A set of 2 or 3 coefficients (β and γ, or β, γ and δ) can be entered to calculate predictions using data sets imported to BUCK. The predictions with the three-coefficient (nonlinear) taper model should be better than those generated by BUCK's fitting algorithm using the two-coefficient taper model obtained via linear regression. The same procedure should be followed to use height-*DBH* curve coefficients defined outside BUCK.

To use an externally defined model(s):

- Select **<Enter Model>** (Figure 8) from the drop-down menu (selected from **<Data/Model>** option in the main menu)
- Import the desired data set by selecting **<Import Data>** and desired file
- Enter the **coefficients** into the appropriate cells below the data display window
- Select **<Apply>** to generate a report on the application of the model

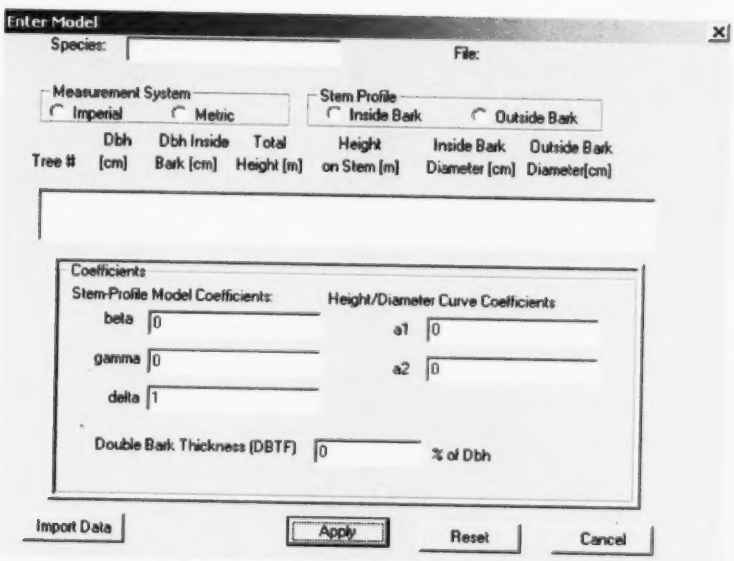


Figure 8. *BUCK's Enter Model window illustrating where coefficients of externally defined models are entered.*

Calibration Results

Accepting the calibration results requires some experience and knowledge of statistical procedures and model evaluation standards. BUCK provides the user with *rule of thumb* criteria to aid in evaluating the results. The output screen displays tables of calibration results for each of the models. The **Statistics of Fit** column displays the parameter names. In the adjacent columns are the values resulting from BUCK's fitting algorithms (**Your Model**), and the suggested rule of thumb criteria (**Recommended Values**).

Critically compare the values in the columns **Your Model** and **Recommended Values**, and visually inspect the graphs of prediction errors for volumes and diameter presented for Zakrzewski's stem profile model (Figure 9). Volume and diameter errors should be randomly distributed around (above and below) the horizontal zero line. Based on this evaluation, the user decides whether to use the model to generate a timber product mix yield table.

Generating a Local Yield Table

To define the format of the local yield table that will be generated by BUCK using the results of the calibrated models, select **<Yield Table>** from the main menu and **<New Table>** from the drop-down menu.

If the table was previously created and saved in BUCK format with the extension **.bck**, select **<Yield Table>** and **<Import Table>** options to display the table for viewing, model re-calibrating, or printing. BUCK format implies that the yield table is saved in computer memory with all the background data and user defined setup (stem analysis, timber standards, etc.). This includes:

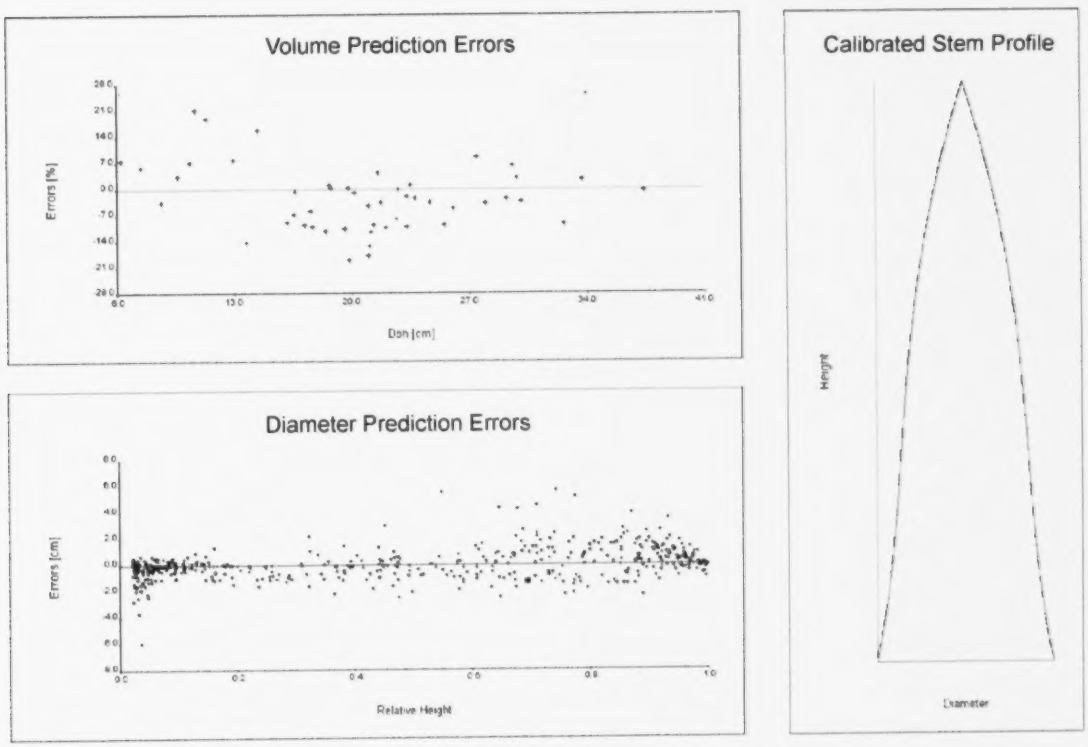


Figure 9. *Example of BUCK output: a calibrated stem profile, and volume and diameter errors plotted vs. DBH and relative heights for the example data set.*

- Timber product specifications
- Timber product size standards
- Timber product rankings (to identify priorities for merchandizing a stem)
- Intervals and ranges for *DBH* and heights, stump height, and kerf (to be used in the yield table)

Timber Requirements. Executing the selections **<Yield Table>** and **<New Table>** opens the tabbed window **Timber Requirements** (Figure 10) that is used to specify timber products and generate local yield tables.

Use the left tab, **Timber Product Requirements**, specify the units of measure for log lengths and top diameters inside bark for the product types, length and minimum diameter dimensions for **Sawlog Classes**, **Veneer Logs,** and **Pulp Logs**, and **Product Rank** for all product types. Numbers can be entered here, or imported from a BUCK file with the extension ***.trq**. Two systems of measure are permitted within one standard table (e.g., log lengths in feet, and diameters in cm).

Once saved, tables with timber standards may be edited and re-saved, however, the unit of measure (imperial/ metric) chosen when standards for edited tables are defined cannot be changed.

BUCK includes the following timber categories:

1. Sawlogs
2. Veneer logs
4. Utility poles
5. Other wood
3. Pulp logs

Two types of timber standard options are available: one is used to define log products and rankings and the other is used for utility pole standards. First, enter the desired timber product standards and ranks. If utility poles are of interest, specify optimization criteria (to maximize pole lengths or top diameters) (Figure 11); the default is maximum pole length.

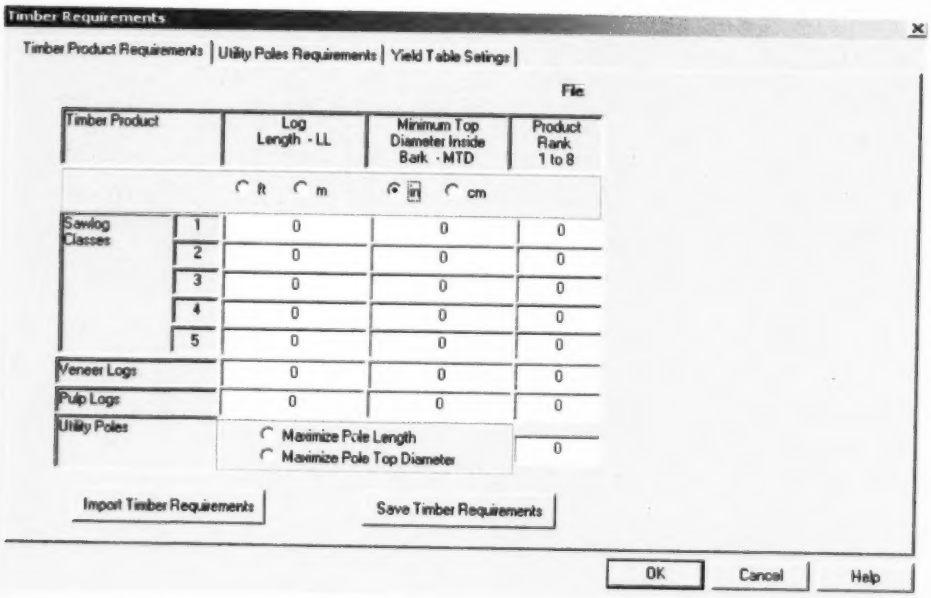


Figure 10. *BUCK's timber product requirements window illustrating where log size and desirability (ranking) are defined.*

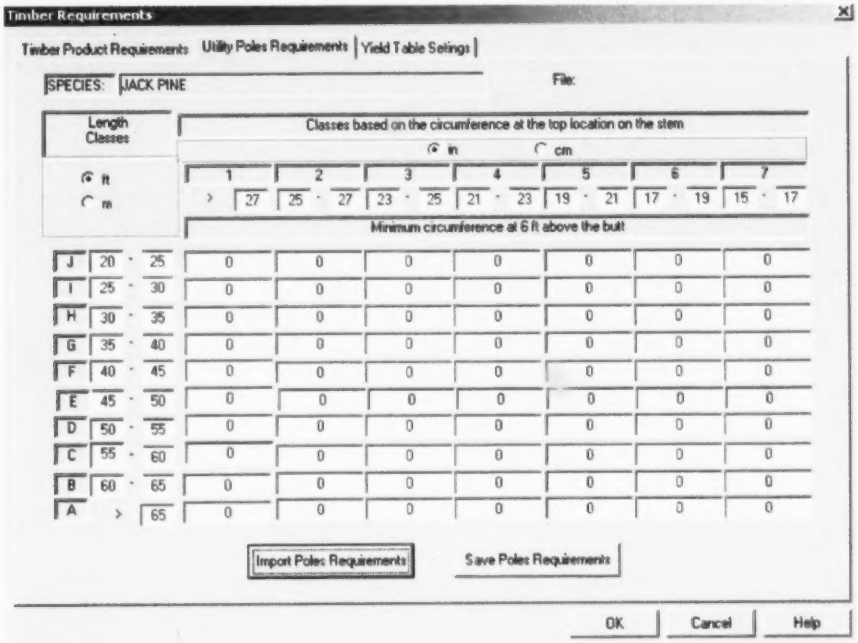


Figure 11. *BUCK's window for defining log size based on utility pole requirements.*

Standards are saved in files with the extensions **.trq** (**Timber Product Requirements**) and **.prq** (**Utility Pole Requirements**). Files created with the above extensions can be imported, edited, and used to generate yield tables.

When entering **Timber Product Requirements** (Figure 10) the user defines **MTD** (minimum top diameter) in terms of inside-bark diameter. If the taper model was calibrated for outside-bark diameters, **MTD** is entered as outside-bark diameter.

Timber Product Requirements are not species specific. It is expected, however, that the timber standards entered or imported are appropriate for the species in question. Standards are labelled by file name (a species name could be used, e.g., LoblollyPine.trq).

Utility Pole Requirements (Figure 11) are species specific — the user enters a species name when the standards are defined. Standards cannot be entered until a species name is declared. If a **.prq** file is imported, the name of the file and the name of the species are displayed.

Defining Yield Table Settings. Select **Yield Table Settings** to define yield table parameters (Figure 12). Cells are provided to enter parameters used in merchandizing stems: **Stump Height** and **Kerf** (in inches or centimetres). The user enters a range and an interval (**Step**) for *DBH*s (outside bark) to be used in generating the table as well as an interval (**Step**) for heights (e.g., 6 ft). If tree-specific yield estimates are to be used for generating a stand-level table, these intervals should be set according to the intervals accepted for the stand-level operational timber cruising data (to ensure the respective files can be merged). For a given *DBH*, within the selected range of *DBH*s, BUCK calculates a lower and an upper height limit (integers) to be used to generate the yield table. These limits are determined by confidence intervals calculated for the height/*DBH* curve for the data used in the taper model calibration step. The user may arbitrarily increase or decrease (proportionally) the range of heights to be used for generating the yield table for the selected range of *DBH*s. This may occur, for example, when yield needs to be estimated for a tree (measured for *DBH* and *H* during operational cruising) that exceeds a range of sizes of sample trees used for taper model calibration. In general, a yield table should be generated for a range of tree sizes matching the range of sample trees used for taper model calibration, however, in practice the user may expect reasonable yield estimates for a wider range of tree sizes.

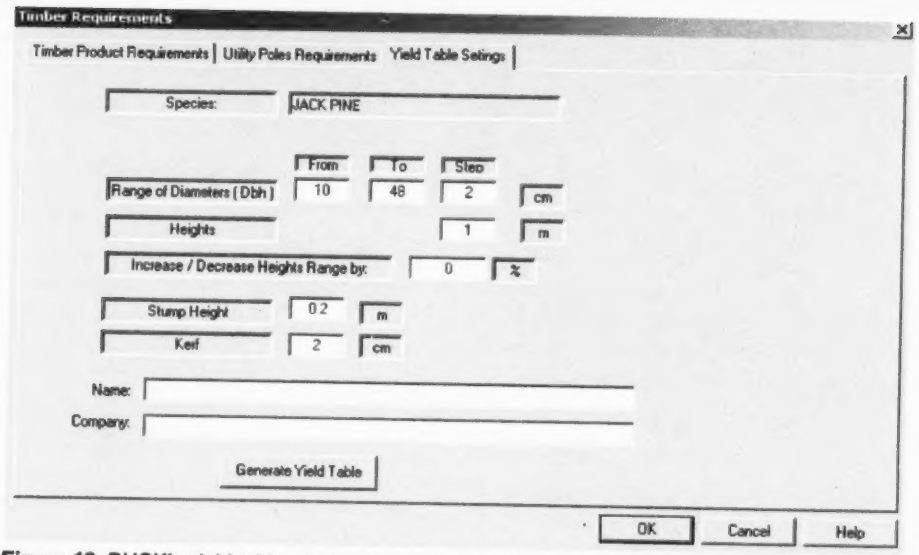


Figure 12. *BUCK's yield table window in which the desired parameters of the optimized timber product mix yield table are entered.*

Additional information requested from the user are the **Company** name and **Name** of the person generating the yield table. Date, timber products, and original stem analysis data file names, etc., are read into the table automatically.

To generate a Local Timber Product Yield Table select **<Generate Yield Table>**. This will generate a report that includes a title page, tables with volume estimates (Figure 13), documentation of the timber size standards used to generate the table, and statistics related to model fitting results.

BUCK

Version 2.0

Dbh = 34.0 cm Species: JACK PINE Stump: 0.20 m Kerf: 2.00 cm

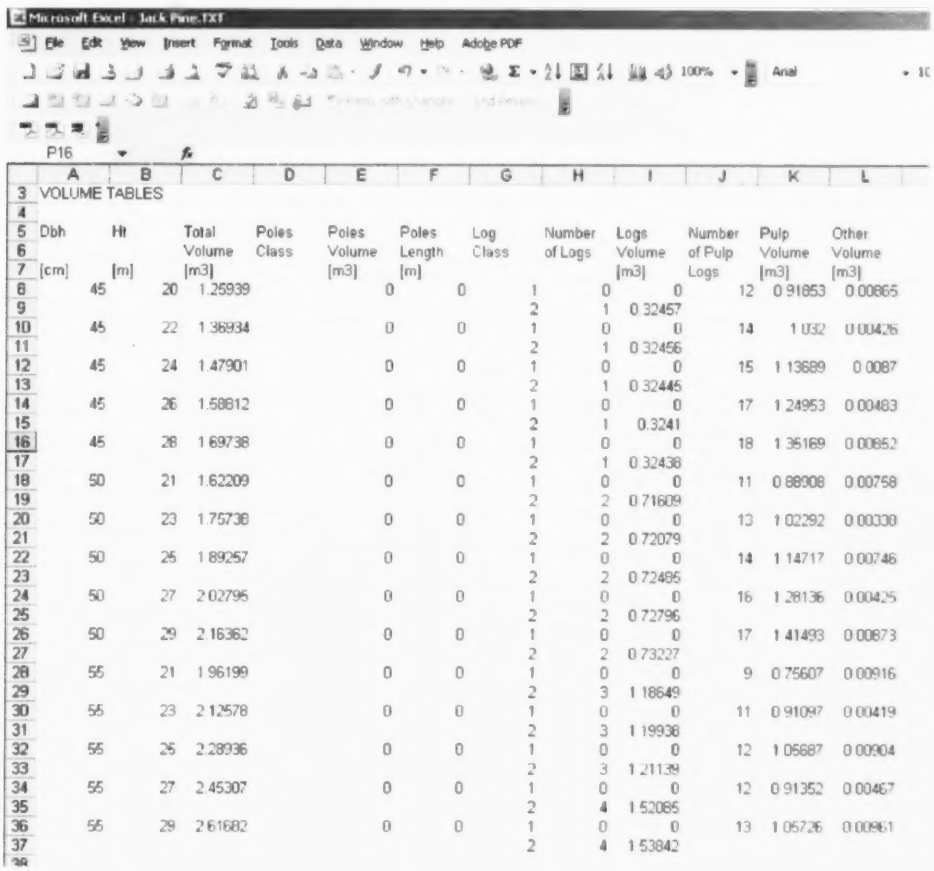
Ht [m]	Gross Total Volume (no stump) [m3]	Poles Class	Poles Volume [m3]	Poles Length [m]	Log Class	Number of Logs	Logs Volume [m3]	Number of Pulp Logs	Pulp Volume [m3]	Other Volume [m3]
18.0	0.65676	I1	0.51172	8.95	1	0	0.00000	2	0.01746	0.00107
					2	0	0.00000			
					3	1	0.07773			
					4	1	0.04733			
					5	0	0.00000			
					Veneer	0	0.00000			
19.0	0.68829	I1	0.52444	9.14	1	0	0.00000	2	0.02365	0.00378
					2	0	0.00000			
					3	1	0.08124			
					4	1	0.05301			
					5	0	0.00000			
					Veneer	0	0.00000			
20.0	0.71945	I1	0.52947	9.14	1	0	0.00000	1	0.00691	0.00219
					2	0	0.00000			
					3	1	0.08563			
					4	1	0.06035			
					5	1	0.03253			
					Veneer	0	0.00000			

Figure 13. *Example of a timber product yield table generated using BUCK software.*

The report containing a series of tables may be printed. Values used for generating the yield table can be saved in a text file (*.txt) that is compatible with spreadsheet programs (e.g., MS-Excel), where columns in the spreadsheet are defined by headers produced by BUCK (Figure 14).

To obtain total volume of timber products (total number of logs) available from a stand (on a per ha basis), one needs a number of trees per hectare for a particular *DBH* class associated with a specific tree height for that class. Multiplying number of trees per ha (for a specific DBH and height) by the respective volumes results in estimate of total volume per ha of specific products. For example, for 15 trees (per ha) of *DBH* = 45 cm and Height = 28 m, inside-bark volume of class 2 logs will be 0.32438 x 15 = 4.8657 m^3 (15 logs) and 20.2753 m^3 pulp logs (18 x 5 = 90 logs) (see Fig. 14). The yield table can be produced for any desired resolution (e.g., for DBH in 1 mm intervals and tree heights in 10 cm intervals).

As was mentioned, the results of merchandizing stems can be linked to the output commonly generated by timber cruising software. The standard output of such a software program includes number of trees within *DBH* classes. Tree heights for given *DBH* may be also available (if stand level height/*DBH* curves are generated by the software). In this case, linking those height/*DBH* pairs of known frequencies with the matching rows in the MS-Excel file is necessary. If heights are not measured in the field, *DBH* is used to link frequencies in *DBH* classes with the respective rows in BUCK's table. Heights used to calculate volumes will be those generated by BUCK from measurements of sample trees used to calibrate the taper model (region-specific general height/*DBH* curve).



Microsoft Excel - Jack Pine.TXT

File Edit View Insert Format Tools Data Window Help Adobe PDF

P16

	A	B	C	D	E	F	G	H	I	J	K	L
3	VOLUME TABLES											
4												
5	Dbh	Ht	Total Volume	Poles Class	Poles Volume	Poles Length	Log Class	Number of Logs	Logs Volume	Number of Pulp Logs	Pulp Volume	Other Volume
6												
7	[cm]	[m]	[m3]		[m3]	[m]			[m3]		[m3]	[m3]
8	45	20	1.25939		0	0	1	0	0	12	0.91853	0.00865
9							2	1	0.32457			
10	45	22	1.36934		0	0	1	0	0	14	1.032	0.00426
11							2	1	0.32456			
12	45	24	1.47901		0	0	1	0	0	15	1.13689	0.0087
13							2	1	0.32445			
14	45	26	1.58812		0	0	1	0	0	17	1.24953	0.00483
15							2	1	0.3241			
16	45	28	1.69738		0	0	1	0	0	18	1.35169	0.00852
17							2	1	0.32438			
18	50	21	1.62209		0	0	1	0	0	11	0.88908	0.00758
19							2	2	0.71609			
20	50	23	1.75736		0	0	1	0	0	13	1.02292	0.00330
21							2	2	0.72079			
22	50	25	1.89257		0	0	1	0	0	14	1.14717	0.00746
23							2	2	0.72486			
24	50	27	2.02795		0	0	1	0	0	16	1.28136	0.00425
25							2	2	0.72796			
26	50	29	2.16362		0	0	1	0	0	17	1.41493	0.00873
27							2	2	0.73227			
28	55	21	1.96199		0	0	1	0	0	9	0.75607	0.00916
29							2	3	1.18649			
30	55	23	2.12578		0	0	1	0	0	11	0.91097	0.00419
31							2	3	1.19938			
32	55	25	2.28936		0	0	1	0	0	12	1.05687	0.00904
33							2	3	1.21139			
34	55	27	2.45307		0	0	1	0	0	12	0.91352	0.00467
35							2	4	1.52085			
36	55	29	2.61682		0	0	1	0	0	13	1.05726	0.00961
37							2	4	1.53842			

Figure 14. *Example of a timber product yield table generated using BUCK, saved in text file format, and subsequently opened using MS-Excel.*

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Appendices

I. Program Access and Installation Instructions

Both programs (Visualizer V. 2 and BUCK V. 2) are available from the Great Lakes Stem Profile Modelling Project (GLSPMP) website:

http://ofri.vancouversolidcomputing.com

- Enter the site as guest/guest (username and password, respectively)
- Browse the folders to find the setup programs
- Download the installation programs and sample data sets and install them

The software is designed to work within the Microsoft Windows operating framework.

The installation program will create the subdirectories **C:\Program Files\SDMS\ VISUALIZER** and **C:\Program Files\SDMS\BUCK.** The user's manual (in Acrobat Reader format) will be placed in the subdirectory **C:\Program Files\SDMS.** It is also available separately from the website.

II. Data Sets Included in SDMS

Nine data sets (readable by Vizualizer V. 2.0) are included in the SDMS V. 2.0 database (Zakrzewski and Schnekenburger 2006). They are described briefly below. Data set names refer to the individual(s) (e.g., Dr. Terry Honer) or the organization (e.g., Kimberly-Clark) that collected the data or the jurisdiction from which data were collected (e.g., Northeast Region). Data users (and data owners) are responsible for "cleaning" the data. This may involve comparing the original records (paper tallies) with those in the database, using interpolations, deleting records, etc.

Beckwith data set. Includes stem analysis data from more than 1300 trees from thinned stands from various permanent sample plot installations in Ontario established by the Ontario Tree Improvement and Forest Biomass Institute (now OFRI). In the early years, stem diameter information was gathered by sectioning the felled trees into 4 and 8 foot lengths (about 122 and 244 cm, respectively). A ruler was used to measure (in two directions) the inside-bark diameter for the bottom of each section. In the early 1980s, as computer-aided stem analysis applications were being developed, a "Digimic" system along with the Tree Ring Increment Measurement (TRIM) system were used to measure ring widths (and ultimately diameter) for multiple cookies sectioned from trees.

Boise Cascade data set. Includes detailed diameter and height increment for 98 jack pine trees from permanent sample plots (PSPs) established by Boise-Cascade Ltd. in jack pine-dominated stands. These PSPs were located in the Kenora and Fort Frances area (boreal forests of northwestern Ontario). Five trees per plot, representing one tree from each of 5 size classes present on the plot, were felled and sectioned. TRIM System was used to assess diameter and height increment for each tree section.

Hansen data set. Includes over 9600 trees measured on 590 commercial logging operations in 5 states (Illinois, Minnesota, Missouri, Wisconsin, and Michigan), involving 62 different species, and forms part of the North Central FIA utilization data set. Sampling occurred over a 15-year period (1981 to 1996) to assess the utilization of harvested timber in the North Central Region. A cross-section of trees harvested for both pulpwood and saw timber were selected from cooperating loggers on both public and private lands.

Honer data set. Includes over 9300 trees, mainly softwoods, from natural stands across Canada. A subset of Ontario data consists of measurements from 3350 trees. Data collection was initiated in 1964 by T.G. Honer at the Forest Management Institute in Ottawa, Ontario, and resulted in the institute's Tree Data Bank.

Kimberly-Clark data set. Includes stem analysis data for 120 jack pine trees from measurements of PSPs established in the 1950s by Kimberly Clark Ltd. in jack pine-dominated stands; PSPs were located in the Longlac-Geraldton area (boreal forests of northwestern Ontario). Five dominant trees per plot, representing 1 tree from each of the top 5 diameter classes present on the plot, were felled and sectioned for stem analysis. Representative trees were selected beyond the plot boundary.

MacFarlane data set. Includes stem analysis data for over 800 trees. The data collection project was initiated and completed in 2004; the objective was to validate current Michigan DNR volume equations as well as to support the Great Lakes Stem Profile Modelling Project by developing new models for Michigan. Data was collected at 19 sites: 6 in the Upper Peninsula and 13 in the Lower Peninsula of Michigan. Study locations covered a range of stand types, harvest types, and geographic locations on Michigan DNR timberlands (and some private lands). Where possible, equal numbers of trees in each of 5 *DBH* size classes: 4.6-9.5", 9.6-13.5", 13.6-19.5", 19.6-24.5", and over 25" (11.5-24, 24.5-34, 34.5-50, 50.5-62, and over 62.5 cm, respectively). Sections of main stem and branches were measured. Stump height and the length of each stem section and diameter inside and outside bark, measured in two perpendicular directions, were recorded. Trees with excessive defect, with unusual form, or with dead or missing tops were excluded from sampling.

Northeast Region (NER) data set. Includes detailed diameter and height increment for 174 older jack pine trees. This stem analysis data supported the investigation of longevity of older jack pine trees. Temporary sample plots were established north of Massey, Ontario (transitional-boreal forests of northeastern Ontario). In addition, 5 trees per plot were felled and sectioned for stem analysis. These trees represented 1 tree from each of 5 size classes present on the plot. Measurements involved using a TRIM System to define diameter (ring measurements) and height increment for each tree section.

Van Dyck data set. Includes data for over 1200 trees. Data collection, led by M. Van Dyck, was initiated in 2001 by the USDA Forest Service (Eastern Region and the Forest Management Service Centre) and is on-going. The ultimate objective of the project is to replace the existing volume estimation procedures with a system based on a taper model. Samples were taken from National Forest areas in the Great Lakes states (Minnesota, Michigan, Wisconsin), and many other states of the Eastern Region. Sampling was conducted to measure trees from a cross-section of species and sizes from a range of site conditions. Trees with severe damage or deformities were not sampled.

Towill-Bowling data set. Includes data for 267 trees (72 jack pine, 195 aspen) from northwestern Ontario. The jack pine stem measurements came from MNR's regional jack pine storability project (1986-90); Kimberly Clark permanent sample plots and Boise Cascade continuous inventory plots were an additional source of sample tree data. Trembling aspen measurements were from both Northcentral and Northwestern Ontario locations. Measurements were collected as part of MNR's site quality evaluation project (1989-1991). Jack pine ranged from 11.1 to 33.8 cm (*DBH*) and 14.2 to 25.9 m (height); ranges for aspen were: 8.3 to 56.1 cm and 9.4 to 27.7 m, respectively.

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